Protecting FOREST TREES and their SEED from Wild Mammals

(A review of the literature)

by M. A. RADWAN

PACIFIC NORTHWEST
FOREST AND RANGE EXPERIMENT STATION
U.S. DEPT. OF AGRICULTURE · FOREST SERVICE

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INTRODUCTION

An extensive literature points to wild mammals as agents that may seriously reduce the productive capacity of forests and, in many ways, interfere with efforts to grow valuable trees. While this loss of forest values is not a new problem, it has been brought into sharper focus through better identification of the various kinds of mammal-caused injuries and by improved survey techniques. These latter actions have been spurred by the high values now attached to forest products and consequent emphasis on early regeneration of timber stands.

Mammals may attack various parts of the plant at different stages of its development to produce injuries differentiated in type, intensity, and effect on growth and development. Wild mammals may also prefer certain plant species and even certain individuals of a species *(68)*. Limited investigation, however, has not linked animal preference to such tree properties as succulence *(111)* or content of protein *(26)*, vitamin *(171)*, or phosphorus *(59)*.

Wild mammals which cause damage to trees and create problems for the forest manager range in size from the tiny shrew to the gigantic elk. A number of wild mammals known to cause damage are listed in the appendix.

Most injury to forest trees comes from animal feeding activities, resulting in seed destruction, cone severing, browsing, clipping, bud nipping, seedling pulling, tree cutting, and debarking. Other injuries, mainly trampling and rubbing, are caused by movements of large animals.[1]

Effective control measures must be devised to combat destructive mammals if adequate forest production is to be achieved. Although progress has been made in recent years toward improving protection measures, the amount of forestry research on wild mammal control is still inadequate.

This paper summarizes some published research on the control of wild mammal damage to forest trees.[2]

MEANS OF PROTECTION

Reduction of Mammal Populations

Biological

Predators.—Protecting and introducing predators has been suggested by some investigators *(91, 146)* as a means of reducing rodent densities and damage to seeds and seedlings. Howard *(78)*, however, pointed out that predators are of little significance in regulating rodent densities. He believes that rodents control predator populations, rather than the reverse.

Diseases.—Introducing a disease among problem mammals as a method of control has been hesitantly considered because of the conflict in general acceptance of a given animal as a pest, coupled with the possibility that introduced diseases may spread to game animals. The method,

[1] Reported types of wild mammal damage to forest trees, motivation therefor, the animal responsible, and references to literature are contained in the appendix.

[2] The survey of literature was completed in December 1961.

however, was successfully utilized in Australia *(67, 125)* by releasing the myxoma virus, the causative agent of a disease called myxomatosis, to control the European rabbit *(Oryctolagus cuniculus)*.

Chemosterilants.—In recent years, entomologists and bird-control specialists have recognized the value of chemosterilants. Investigations with chemicals that induce sterility in insects and birds are now in progress. Toxic agents that would reduce the population are mixed with chemosterilants that would destroy the reproductive ability of the survivors. This principle has never been used in forestry in the control of wild mammals, and its evaluation would be highly desirable.

Trapping and Shooting

Trapping or shooting can be used to reduce the population of large mammals, but these methods are impractical for the control of small rodents in forests *(91, 146)*. Hunting and trapping are both used to control bear in western Washington *(102)*, and hunting to control porcupines is practiced on high-damage areas in the ponderosa pine region. The value of legal hunting of deer and elk has also been generally recognized. Many foresters recommend its intensification *(2)*, especially on young plantations *(91)*.

Poison Baits

Seeds, fruits, or roots formulated into poison baits with strychnine, zinc phosphide, compound 1080,[3] warfarin,[4] thallous sulfate, tetramethylenedisulphotetramine (tetramine),[5] sodium arsenite, or some other rodenticide have proven useful or have shown promise of becoming useful as a practical means of controlling some forest rodents. Investigators have recommended various formulations of poison baits to control meadow mouse *(81)*, wood rat *(76, 115)*, mountain beaver *(135)*, pocket gopher *(45)*, hare *(14)*, and porcupine *(47)*.

Much of the literature on the subject deals with attempts to control seed-eating mammals. Spencer and Kverno *(151)* reported some success with tetramine. In the Douglas-fir region, the two most commonly used poisons are compound 1080 and thallous sulfate applied to wheat or hulled sunflower seed. However, this treatment is not recommended for seeds with intact, inedible hulls because rodents usually cut through poisoned hulls and eat seed contents without being appreciably poisoned.

Compound 1080 gave good initial rodent control when used alone *(52,72,116,161)* or in combination with thallous sulfate *(11)*, but the hazard of secondary poisoning from this compound, compared with that from thallous sulfate, limits its use. Baiting with seed treated with thallous sulfate controlled seed-eating rodents sufficiently to produce satisfactory stocking in both natural *(88)* and artificial *(138)* seeding programs. This method, however, gives only very short periods of control because of rapid reinfestation from untreated areas *(146)*. With current poison bait control methods, rebaiting is often practiced unless buffer strips are included in the initial baiting operation *(11, 72)*.

[3] Sodium fluoroacetate.

[4] 3-(alpha-acetonylbenzyl)-4-hydroxycoumarin.

[5] 2,6-dithia-1,3,5,7-tetrazatricyclo $(3.3.1.1.^{3,7})$ decane-2,2,6,6-tetraoxide. See Appendix for additional information.

Contact and Systemic Poisons

In recent years, the trend in protecting seed and seedlings from wild mammals has been toward the use of poisonous and repellent chemicals applied to the tree or seed. Poisonous chemicals are of two general types: "contact," those which remain on the surface of treated plants, and "systemic," those which are absorbed and translocated by the plant. Contact poisons do not provide protection to new shoots produced after the plant has been treated. A systemic poison, on the other hand, should be effective on the whole plant, including all new growth produced for some time after treatment.

Tetramine.—In 1951, the Denver Wildlife Research Laboratory introduced tetramine for treating coniferous seed. Experiments showed the chemical to be nonphytotoxic, stable *(94)*, and very sparingly soluble. In laboratory tests, treatment of seed with this highly toxic chemical was found to extend protection from rodents to newly formed seedlings with no harmful effects to form or growth rate *(150, 151)*. First field trials on seed treated with a 1-percent solution of tetramine in acetone were effective in controlling rodents, protecting tree seed, and improving the stocking of areas seeded with Douglas-fir *(50, 73, 74, 142)* or ponderosa pine *(63, 151)*. The tetramine-acetone treatment, however, presented many difficulties. Even after modification *(152)*, it continued to reduce germination *(50, 73, 96, 142, 151)* and cause seedling mortality *(142)*. Attempts to reduce the loss in germination, which was thought to be caused mainly by the acetone *(151)*, led to coating seeds with an adhesive containing tetramine. Although the detrimental effect on germination persisted *(44, 50, 130)*, satisfactory stocking of Douglas-fir *(44, 50, 96)* and ponderosa pine *(63, 130)* was obtained.

Tetramine has been suggested as a seedling treatment for decimating hares *(94)* and under certain conditions may be superior to endrin in protecting seed *(44)*. Although some of the properties of tetramine have been determined *(64, 164)*, we have no information on toxicity and effect on metabolism, degree of storage, and excretion of the compound in big-game animals. The extreme toxicity of tetramine to man and wildlife and the hazard that may be created by its use make determination of its effect and its behavior in animals a prerequisite to devising a safe control method for treating seedlings in the field. The hazard question also emphasizes the necessity for additional research in connection with evaluating proposals *(94)* for establishing toxic feeding stations where a buried reservoir of the chemical would be available to the seedlings. Whether this tetramine would be available to other vegetation (e.g., berries, salal, grass, etc.) and whether this would constitute a hazard is still unknown. Determination of leachability, distribution, and stability of tetramine in the soil and the relative absorption, translocation, and degradation of the chemical by different plant species would certainly be helpful in clarifying this point *(124)*. Similar studies would be required in evaluating the proposal that a few trees treated with tetramine in the nursery be included in new plantations *(94)*.

To establish a safe and effective nursery practice, the fate of tetramine in nursery soil must be determined. Knowledge of the behavior of the chemical inside the plant is also necessary to explain the reaction of animals to the treated seedlings in the field. Additional research should be aimed at counteracting the undesirable effects of acetone or discovering a nontoxic solvent. In addition, reevaluation of the chemical must depend on a careful comparison with endrin, such as effect on seed embryos, ease of impregnating seed, and performance of treated seed and newly emerged seedlings in the field.

Endrin.—In spite of the relatively successful use of tetramine, the chemical never became commercially available *(149)*, and it was necessary to find another protective agent to replace it in seed treatments. For this purpose, the U.S. Fish and Wildlife Service *(163)* recommended endrin,[6] a nonphytotoxic, commercially available insecticide. This was used in a seed-coating formulation containing an adhesive, the fungicide "thiram"[7] and aluminum powder *(149)*.

The formulation was somewhat effective in protecting coniferous seed from destruction by some rodents *(42, 44, 75, 96, 133)* but was ineffective against ground squirrel populations *(148)*. It also inhibited seed germination *(44)* and, while this may have been due to thiram *(96, 143, 149)*, the adhesive or endrin itself may have contributed to the adverse effect.

Tetramine and endrin coating treatments were also used in attempts to protect natural seed from rodent destruction by first exposing the rodents to artificially sown, treated seed of the same species. This method, however, proved ineffective because the rodents apparently avoided the treated seed *(43, 96)*.

Endrin has also been used in attempts to protect seedlings from damage. Burns *(28)* sprayed 35 different toxic formulations on loblolly pine (*Pinus taeda* L.) seedlings and found that endrin was the most effective. Meadow mice were controlled in Germany by spraying grasses and other vegetation with 0.01-percent endrin emulsion *(92)*, and satisfactory *Microtus* control was obtained in England *(71)*.

Since its introduction in 1956, the endrin formulation has not been materially changed, and effects of its components on seed and seedlings are not known. Until a repellent compound or a more effective toxicant with lower toxicity to humans and beneficial wildlife is discovered, the endrin treatment requires more investigation, particularly in connection with effects of its components on seed viability and survival of seedlings from treated seed. Development of an impregnating technique *(93)* is also needed—provided endrin proves nontoxic to seed embryos *(124)*. Such a technique would increase effectiveness of the treatment and may prove useful in cases where the coating treatment usually fails.

Strychnine.—Many toxic chemicals have been applied to seedlings and even to the ground vegetation to reduce hare and mouse damage to small trees. Use of such chemicals, however, will always be a calculated risk with respect to the safety of beneficial wildlife and domestic livestock.

Strychnine was one of the first toxicants so used. The U.S. Forest Service and other agencies used planting stock sprayed with adhesives containing strychnine, but reports on effectiveness of the spray were conflicting and inconclusive *(91, 169)*.

Toxaphene.—Good control of meadow mice was obtained in Germany by spraying grasses and other surface vegetation with 0.05-percent toxaphene emulsions.[8] Painting individual plant stems with toxaphene gave protection against both mice and rabbits and was not harmful to deer *(107)*. Satisfactory protection of young seedlings and high levels of mouse *(Microtus)* control were also obtained in preliminary experiments in England *(71)*.

[6] 1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4-endo, endo-5,8-dimethanonapthalene. See Appendix for further information.

[7] Tetramethylthiuram disulfide.

[8] Chlorinated camphene (67 to 69 percent chlorine).

Duration of protection.—Strychnine, endrin, and toxaphene are believed to be contact toxicants. Apparently they are not absorbed and translocated by the plant and thus do not provide protection to new shoots produced after the seedling has been treated. Protection is confined to the treated parts and probably lasts as long as the toxicant is present in sufficient concentration.

Long-term protection, on the other hand, might be obtained with systemic toxicants capable of being translocated into the new growth either from root or foliage applications. Kverno *(94)* found that a single soil treatment with tetramine produced toxic foliage for 4 years. He hypothesized that toxic plant feeding stations within deer-proof enclosures could be used for reductional control of hares. He also suggested treating a small proportion of the seedlings in a plantation, sufficient for controlling hares but at levels low enough not to endanger deer. The practical value of these ideas has not been demonstrated although work is now underway to evaluate them *(95)*. The future of any tetramine treatment as well as other systemic toxicants will depend largely on success in developing safer and more economical methods of use.

Manipulation and Exclusion of Mammals

Cultural

Improved seeding, planting, and stand-improvement techniques.—There is always a place for intelligent application of cultural practices as a means of alleviating mammal damage. Good ground preparation, covering the seed with mineral soil, and sowing during periods of low rodent population would reduce seed loss to rodents *(146)*. Injury by rabbits and hares could be minimized where feasible by using large seedlings of less palatable but fast-growing species *(9, 165)*. Clean cultivation and use of resistant seedlings would tend to lessen meadow mouse damage *(29, 81)*. Tree pruning might be helpful in reducing bear damage *(57)* and, when used in combination with thinning, could inhibit wood rat housebuilding activities *(76)*.

Supplementary feeding.—Lack of food, a main cause of excessive browsing and clipping, would be relieved by improving existing range conditions and by creating additional foods. Adams *(6)* and Roy *(131)* assumed that maintaining broad-leaved browse species would protect conifers from deer browsing. Rations of felled aspen (*Populus* spp.) were suggested to reduce hare damage *(9)*, and felled spruce provided considerable protection against deer *(80)*. The deliberate planning of deer range as a part of forest management, however, would provide much better protection *(101)*. Bleichert *(22, 23)*, therefore, proposed that from 1 to 3 percent of the forest in small and scattered patches be maintained as pastureland for deer. Planting of such areas to different foodstuffs would promote deer movement and thus reduce time available to debark or browse the trees *(140)*.

Weed and brush control.—Brush and weeds can be serious competitors to trees for moisture and nutrients. Moreover, they furnish ideal habitat for some rodents. High populations of meadow mouse are found only on areas supporting a moderate to heavy herbaceous cover *(29, 103)*. Hares, on the other hand, prefer brushy cutover lands *(111)*. Several workers have suggested eliminating or reducing vegetation density, presumably through cultivation, to minimize hare *(9)* and mouse *(29, 103, 118)* damage. Chemical weed and brush control offers many advantages over conventional cultivation methods, but only one account of the use of herbicides has been reported. Experiments at Colorado State University *(33)* have shown that 85 to 95 percent of pocket gophers die off 1 year after ranges are sprayed with 2,4-D.[9] These experiments demonstrate possibilities of the method and should stimulate further research.

[9] 2,4-dichlorophenoxyacetic acid.

Plant growth regulation.—Although growth regulators are used extensively in modifying growth and development of agricultural and horticultural plants, very few have been used in forestry. However, it is possible to develop these and other chemicals to achieve the same ends on forest tree seeds and seedlings. Several possibilities for animal-damage control appear evident. If seed would germinate sooner and height growth increase faster, seed and seedling would have a better chance of escaping rodents. Stems would be thicker, lateral shoots stronger, and root systems heavier, thereby increasing seedling resistance to damage and decreasing mortality.

Mechanical

Animal-proof fences to protect trees have been used in American forestry only to a limited extent because of their high cost. In recent years, however, cost of deer-proof fences has been reduced. Grisez *(61)* suggested the use of standing trees for fence support, and Ow *(117)* described a fence of nylon netting which can be tied to trees by nylon ropes.

Screens were used to protect seed spots from rodents as early as 1911 *(120)*. Since that time, screens of different forms have proven beneficial *(52, 144, 109)*. The cheapest and most practical screens, however, are the K-screens (cylinders of hardware cloth with partially closed tops) *(85)* as modified by Roy and Schubert *(132)*. They are not affected by large rodents or weather conditions and need not be removed from seed spots.

In addition to fences and screens, other protective covers and devices have been used with variable success. These include: mulches *(66, 170)*, newspaper pieces *(65)*, beer cans *(82)*, and gelatin capsules *(79)* to protect seed in seed spots from rodents; paper bags *(104)* and plastic strips *(106)* to protect terminal and lateral buds from deer browsing; metal sleeves with projecting prongs to protect trees against deer rubbing *(126)*; and metal bands to prevent squirrels from climbing cone-bearing trees *(153)*.

Systemic and Contact Repellents

Repellent rather than toxic chemicals are less hazardous to man, domestic livestock, and big-game animals and other forms of beneficial wildlife. An ideal repellent should be nontoxic to mammals. It must also be chemically stable over reasonable periods of time; nonphytotoxic; capable of being translocated into the plant; nondetrimental to soil, mycorrhizal fungi, or form and rate of growth of plants; inexpensive; and safe for man to use. Unfortunately, none of the chemicals that have been tested for repellency qualify as ideal.

There is no truly systemic repellent for treating seed or seedlings at this time. Claims of "repellency" attributed to some systemic chemicals appear to stem from lack of a satisfactory definition of the term. Such definition must be achieved to clear up current misunderstanding of what constitutes repellent properties of a chemical. In the meantime, the search must be continued for a truly systemic repellent through screening and testing programs.

Very little success has been reported with chemicals applied to seed or to the soil covering seed spots to repel rodents. Iodoform, naphthalene, iodine, zinc chloride, borax, quinine, tannic acid, carbolic acid, etc. failed to protect coniferous seed from rodents *(170)*. Shirley *(144)* found that red lead and sulphonated linseed oil applied to seed or to the soil after sowing gave only

slight protection. More recently, Schubert *(139)* reported that red lead, zinc phosphide, and compound 1080 proved ineffective against rodents when applied to sugar pine seed. The need for an effective repellent for seed treatment, therefore, still exists.

Attention has also been given to protecting seedlings and trees from animals through use of contact repellents. Early attempts, confined largely to orchard trees, were not particularly successful *(68)*. It remained for the U. S. Fish and Wildlife Service, in cooperation with other Government agencies and chemical companies, to initiate testing of various chemicals in an attempt to discover and develop repellent chemicals suitable for both forest and orchard trees. Due to these efforts, several chemical compounds, in different formulations, were "discovered" and field tested. Repellent "96a" (suspension of copper carbonate, copper sulfate, and lime sulfur in ethylene dichloride, with asphalt emulsion and a synthetic resin as adhesives) was reported successful in preventing damage to trees by rabbits *(167)*. It soon became apparent, however, that organic compounds, especially those containing sulfur, nitrogen, the halogens, or combinations of these elements, were the most active repellents *(16)*.

ZAC and TMTD[10] were tested for 5 years against hares, meadow mice, and deer. Ten-percent ZAC or TMTD reduced damage by hares to Douglas-fir, white and red pine, black and white spruce, ponderosa pine, some deciduous species *(18, 20, 21, 165)*, and loblolly pine *(27)*. Small-scale studies indicate effectiveness in protecting Douglas-fir seedlings and 6-year-old ponderosa and lodgepole pines against meadow mice *(19, 21)*. Evaluated as deer repellents, effectiveness of ZAC or TMTD varied widely with species of deer, kind and size of test plants, amount of deer pressure, and length of test period *(18)*. Browsing of treated ponderosa pine seedlings by mule deer was reduced by 73 percent in central Oregon, but Douglas-fir seedlings were not protected from black-tailed deer in western Washington *(21)*. Trials against deer with these repellents should be evaluated directly on each site where a deer problem exists.

TMTD and ZAC have similar repellent properties, particularly against hares. Spray formulations, however, afford protection to seedlings for a very short period of time and may cause some burning of the needles. When planting stock in the nursery is sprayed, a certain amount of the spray reaches the soil, and the possibility exists that some ingredient in the formulation may inhibit beneficial microorganisms in the soil unless it is degraded or inactivated by some soil factor. Effects of the ingredients and their stability in nursery soils deserve investigation. It is equally important to determine stability of these compounds on plant surfaces and effects on the life processes of the plant.

A large number of commercial repellents have also been tested in other countries with some success. Examples of these repellents and the countries in which they were developed are: "Wiltex" *(12)*, Sweden; "Waldine I" and "Waldine II" *(128)*, Switzerland; "Spangol V" *(157)*, Denmark; "Regensburger Verbiss-und Schalschutzmittel–RVS" *(122)* and "Picetol F" *(123)*, Germany; and "Herbasan" and "Sinoxyd F" *(70)*, England.

The relative effectiveness of these foreign formulations, compared with the American repellents, is not known. However, all available repellents, American and foreign, are of the contact type which protect only the treated portion of the plant, not new growth. Annual applications are necessary for satisfactory protection until seedlings outgrow the reach of destructive animals. This method of application is obviously inadequate in view of the expense of repeated field application.

[10] See Appendix for formulation and other information.

Actidione[11] was found most effective against Norway rats in food acceptance and barrier tests *(168)*. A 1-percent formulation with 10-percent lacquer and 1-percent accelerator was extremely phytotoxic to Douglas-fir *(17)*. Similar formulations were injurious to hardwoods except when treatment was limited to stem application *(70)*.

A 5-percent formulation of TNB-A in an organic solvent mixed with resins provided excellent protection to hardwood tree species against hares *(18)*. Douglas-fir was also protected, but the chemical proved to be somewhat phytotoxic *(17)*. It was harmful to needles of ponderosa and lodgepole pine but basal treatments were nonphytotoxic and fairly effective in reducing damage to 6-year-old seedlings by meadow mice *(18, 19)*.

Bone tar oil, applied directly to Douglas-fir seedlings or as a spray broadcast over planted areas, failed to reduce deer damage *(99)*. This was as a 1-percent formulation with 10-percent rhoplex AC-33 as adhesive and Tween-20 as a stabilizer.

Nicotine sprays gave satisfactory protection to deciduous trees against rabbits *(68)*. Clipping of Douglas-fir by hares was reduced by application of 4-percent nicotine sulfate in an asphalt emulsion, with Triton X151 and Triton X171 as stabilizer and spreader.

A 10-percent aqueous emulsion of TN 2531 with 10-percent rhoplex AC-33 adhesive reduced clipping damage by hares on Douglas-fir, ponderosa pine, and some hardwood species *(17)*. This repellent must be applied within 12 hours of mixing and for this reason was replaced by TN 2500.

A 10-percent aqueous emulsion of TN 2500 with 15-percent rhoplex AC-33 adhesive increased Douglas-fir mortality, delayed emergence of terminal buds of red and white pine, but was not injurious to balsam fir, black spruce, or hardwood species. In all tests, it provided some protection against hares *(20)*. A 5-percent spray produced no phytotoxic effects; reduced deer browsing on ponderosa pine *(18)*, and gave satisfactory protection to Douglas-fir against hare clipping *(165)*.

A 10-percent aqueous emulsion of TMTM (tetramethylthiuram monosulfide) with 10-percent polyethelene polysulfide or 10-percent rhoplex AC-33 adhesives reduced rabbit damage to Douglas-fir and some hardwood species *(17)*. Testing of this compound was discontinued, however, in favor of formulations of zinc dimethyldithiocarbamate-cyclohexylamine complex and tetramethylthiuram disulfide.

Spraying conifer seedlings with 10-percent Z.I.P. solution reduced deer damage during winter *(30)*. This chemical also gave good protection from rabbits to Douglas-fir and some deciduous trees *(17)*.

Area Repellents

Enclosing tree plantations with rope or string impregnated with repellent chemicals has been used experimentally to protect trees from mammals. Eygenraam *(49)* used string impregnated with bone tar and obtained protection against deer for about 2 months. More recently, rope treated with

[11] Additional information on actidione and several other chemicals mentioned in this section is given in the appendix.

an animal tar in a commercial product called "Wam" was reported to have given protection against deer for 6 months *(51)*. The approach, however, is not new and other investigators question its effectiveness in controlling mammal damage *(68)*.

CONCLUSION

Damage to forest trees, seedlings, and seeds by wild mammals is an increasingly serious and, as yet, unsolved problem. Certainly, the economic values involved make it most urgent that we mount an increased research attack.

It is apparent that measures required to achieve control of wild mammal damage to forest values must be of a much more intensive nature than heretofore contemplated. Costs involved in application of mechanical barriers to animals rule out this approach to the problem on the millions of acres of forest land under consideration. Some help can be expected from cultural measures, intensified trapping and shooting of the larger problem animals, and other direct-action methods, but such efforts are feasible only on relatively small areas.

A review of the literature indicates clearly that a promising approach for the eventual control of wild mammal depredations is the improvement of chemical toxicants and repellents. Contact repellents and toxicants are only a stopgap because they protect only current growth. More effective and longer lasting results will require developing and perfecting the use of truly systemic toxicants or repellents.

A number of organizations, both public and private, are now engaged in research to help solve this problem. Screening and testing of chemicals is being done at increasing rates.

Development of new chemicals must be encouraged, aided perhaps by research on vegetation rarely accepted by some mammals. These plants, even though most succulent and probably nutritious, may contain active chemical compounds that make them unattractive to animals. Whether these chemicals are stable and active outside the plant and whether they can be identified and synthesized for use on conifers needs to be explored *(124)*. We also need more information on animal preference for food as a prerequisite to development of control chemicals.

The problem of wild mammal damage to forest values is increasingly serious and complicated in its solution. It can be solved, however, by strengthening the total research effort.

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APPENDIX

Supplementary Information on Some Repellent Chemicals

ZAC. Panogen, Inc., Ringwood, Ill.

("Improved Z.I.P."). Zinc dimethyldithiocarbamate-cyclohexylamine complex with rhoplex AC-33.

TMTD--source Arasan 42-S or Arasan SF-X. E. I. DuPont De Nemours & Co., Inc., Wilmington, Del.

Tetramethylthiuram disulfide. Formulation with rhoplex AC-33 adhesive and suitable defoaming, thickening, and dispensing agents obtainable from Selco Supply Co., Eaton, Colo. ("Selco TMTD-Rhoplex Rabbit & Deer Repellent Concentrate "); formulation containing Arasan 42-S and a modified acrylic resin is available from O. E. Linck Co., Inc., Clifton, N. J. ("TAT-GO"); a 20-percent formulation is also available from Pennsalt Chemicals Corp., Tacoma, Wash. ("Penco Thiram Animal Repellent").

ACTIDIONE. The Upjohn Co., Kalamazoo, Mich.

B-(2-(3,5-dimethyl-2-oxocyclohexyl)-2-hydroxyethyl) glutarimide. Antibiotic.

TNB-A. Panogen, Inc., Ringwood, Ill.

("Ringwood Repellent"). Trinitrobenzene-aniline complex.

TN 2531 (proprietary). Panogen, Inc., Ringwood, Ill.

TN 2500 (proprietary). Panogen, Inc., Ringwood, Ill.

Z.I.P. B. F. Goodrich Chemical Co., Cleveland, Ohio.

("Good-Rite Z.I.P."). Zinc dimethyldithiocarbamate-cyclohexylamine complex with polyethelene polysulfide. Weathering properties are inferior to those of ZAC.

Some Animals Causing Damage to Forest Resources

Order	Suborder	Genera[1]	Common name
Artiodactyla	Ruminantia	*Cervus*	wapiti (elk)
		Dama	deer
Carnivora		*Ursus*	black and brown bear
Insectivora		*Blarina*	short-tailed shrew
		Scapanus	western mole
		Sorex	long-tailed shrew
Lagomorpha		*Lepus*	hare
		Sylvilagus	cottontail and brush rabbits
Rodentia	Hystricomorpha	*Erethizon*	porcupine
	Myomorpha	*Clethrionomys*	red-backed mouse
		Microtus	meadow vole
		Mus	house mouse
		Napaeozapus	jumping mouse
		Neotoma	wood rat
		Peromyscus	white-footed mouse
	Sciuromorpha	*Ammospermophilus*	antelope squirrel
		Aplodontia	mountain beaver
		Castor	beaver
		Eutamias	western chipmunk
		Perognathus	pocket mouse
		Sciurus	tree squirrel
		Tamias	eastern chipmunk
		Tamiasciurus	red squirrel
		Thomomys	pocket gopher

[1] After Hall, E. Raymond, and Kelson, Keith R. The mammals of North America. 2 v. New York: The Ronald Press Co. 1959.

Summary of Reported Wild Mammal Damage

	Literature reference
Seed destruction	
Motivation:	
Feeding	9, 62, 111
Animal causing damage:	
Antelope squirrel	145, 146, 162
Chipmunk	111, 145, 146, 160
Shrew	62, 83, 111, 112
Red-backed mouse	4, 5, 62
House mouse	146
Jumping mouse	62, 146
Meadow mouse	4, 88, 146
Pocket mouse	146
White-footed mouse	4, 5, 24, 62, 88, 111, 112, 146, 160
Effects of damage:	
Prevents or retards regeneration	24, 111, 129, 146, 162
May limit regeneration to species of low value	5, 88
Cone severing	
Motivation:	
Feeding	111
Animal causing damage:	
Red squirrel	8, 153, 160
Effect of damage:	
Reduces current and, possibly, future seed crop	8, 153
Browsing	
Motivation:	
Feeding	10, 26, 36, 46, 141
Animal causing damage:	
Deer	6, 10, 26, 40, 110, 114, 119, 131, 158
Elk	55, 119, 141
Effect of damage:	
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